Barium tagging for a nEXO upgrade and future ^{136}Xe $0\nu\beta\beta$ detectors

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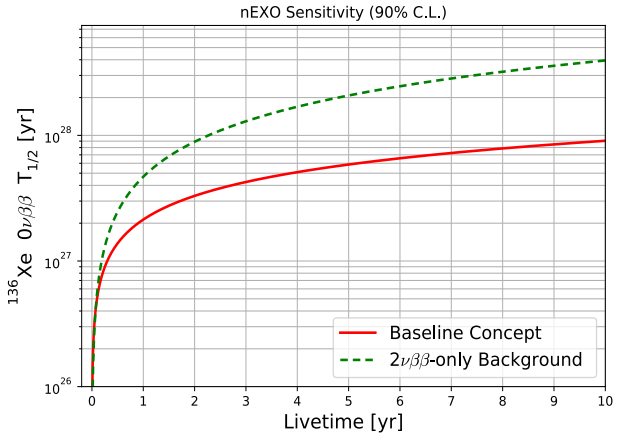
* What is the physics / motivation for your LOI?

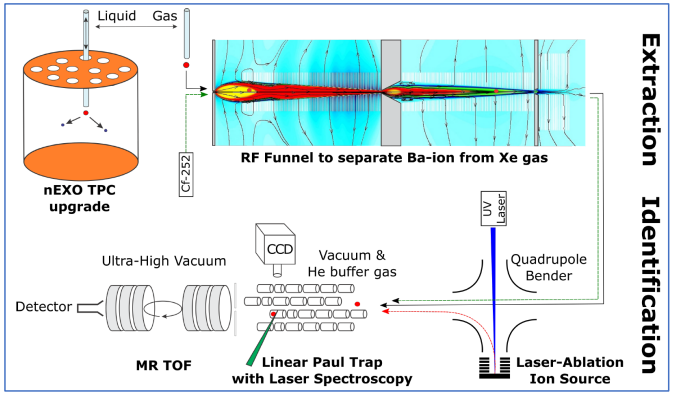
- Next generation experiments at the tonne scale have been proposed to span the possibilities with inverted mass hierarchy and probe partially the normal hierarchy with lifetimes up to about 1×10^{28} years.
- To go a step beyond this next level, it is desirable is to have an additional way to verify if an event produced is actually containing the expected Ba daughter ion. Tagging the Ba daughter will help to reduce background events as much as possible and to use the isotope as efficiently as possible.
- To be prepared for a possible Ba tagging upgrade of nEXO in a 10+ year time frame, a further phase of R&D is envisioned in which extraction of Ba daughters from a LXe TPC is perfected, and Ba tagging of daughters of individual beta decays of Cs isotopes is demonstrated.

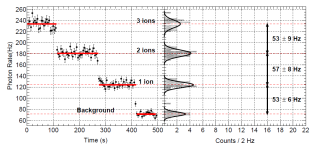


Concept and current work

Among a number of Ba tagging technologies explored in the EXO-200 and nEXO Collaborations over the past two decades, two front-running schemes have emerged. Both methods involve transport of daughter to a Ba identification region, while keeping the daughter ion or atom away from all surfaces that might contain a few other Ba atoms from natural contamination.

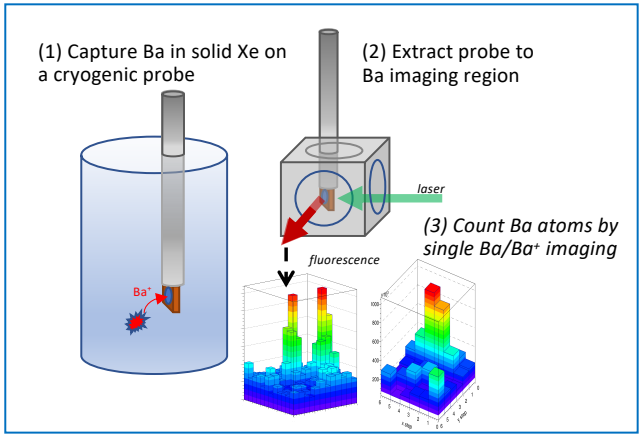
LXe - GXe - Vacuum





Counting of single Ba^+ ions in a linear Paul trap

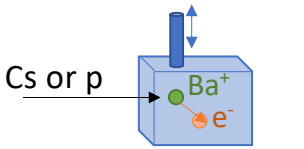
LXe - SXe - Vacuum

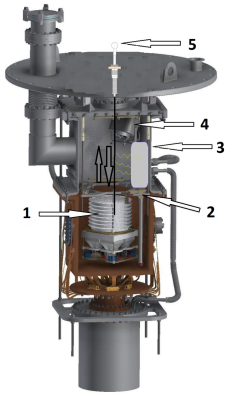


* What will you work on between now and Snowmass, and what is your schedule for developing a contributed paper?

- **Current phase of our Ba tagging research: (previous slide)**
  - demonstrating the basic physics of the ion identification process.

- **Next phase of Ba tagging research (Snowmass process):**
  - Perfect the process of extraction of the ^{136}Xe daughter from a small liquid xenon cell and transport to the Ba identification region
  - Development a method for efficient Ba daughter extraction from all positions in an ~100 kg liquid xenon TPC
  - Measure the efficiency of extraction of the ^{A}Ba daughter ^{A}Cs of from an ~100 kg liquid xenon TPC





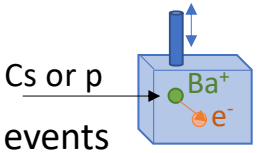
100 kg LXe TPC test apparatus

- We will work on making more well-developed plans for the next phase of our Ba tagging work.
- We plan to prepare a draft contributed paper by Spring, 2021.

Sample of further R&D toward a nEXO upgrade with Ba tagging:

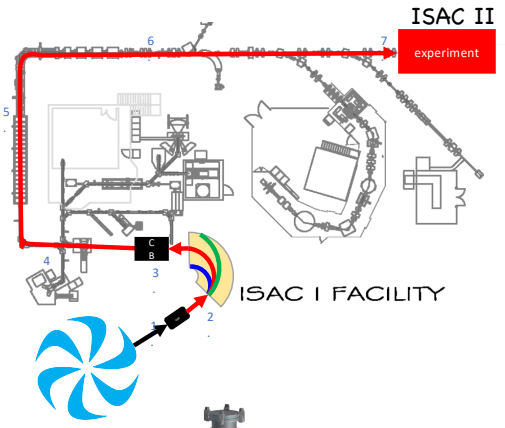
(1) Need quantified source of Ba^+ ions in liquid xenon for extraction studies

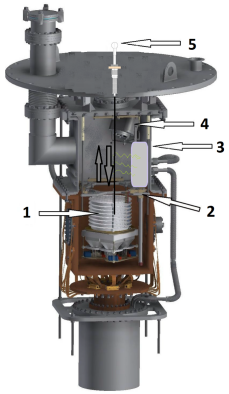
- Deposit or create Cs isotopes that beta decay to Ba in LXe
  - Cs isotopes at CARIBU facility at ANL or ISAC II facility at TRIUMF can be implanted into LXe through foil
  - Create ^{136}Cs in Xe gas or LXe by (p,n) reactions on ^{136}Xe at TUNL or UK
- Study 1-D extraction with a small LXe cell
- Tag extracted Ba daughters
- Check Ba tagging efficiency with single Cs beta decay events



(2) Engineering of 3-D probe extraction method and test in 100 kg LXe TPC

(3) Design and engineering of a new nEXO TPC that accommodates apparatus for Ba tagging





100 kg LXe TPC test apparatus

* What common data sets, joint efforts, etc. do you need?

- We have meetings 1-2 times per month within the nEXO Collaboration to foster joint efforts within nEXO.
- Likely there is significant synergy between the nEXO and NEXT Ba tagging efforts.
  - We will communicate regularly to share ideas and identify areas of where collaborative research could be mutually beneficial.
  - The NEXT and nEXO Ba tagging groups will meet at a workshop in December to discuss joint efforts between collaborations.
  - These steps will help create more of a sense of community in Ba tagging.

* What would you like to come out of the Snowmass process?

- Development of a community of researchers thinking beyond the tonne scale
- Clarify the path toward demonstration of some viable approaches.
- Greater unity and mutual support in the Ba tagging community.
- Recognition of the importance of daughter identification.
- A statement of support for R&D on new methods that go beyond the tonne scale.